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Protect My House: Developing a Family Over the Counter Drug Dosage Chart

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by Rajendra K. Jaini

Introduction to the unit

Students will create a poster for their household that will have a list of common over the counter drugs, along with the correct calculated dosages for each of their family members. This unit is intended to be taught at the beginning of the school year; the goal is to teach and/or fill in core mathematical topics to high school chemistry students who have fundamental gaps in their knowledge. By having students create a product (poster) that directly relates to their family's well-being, I hope to capture their buy-in regarding why they need to learn math skills that apply to life; these are, in fact, the same skills required to succeed in chemistry.

Chemistry is often the first course in the progression of a high school student's science courses in which the students get the opportunity to apply their mathematical skills. In chemistry, students usually want to know 1.) why they have to learn so much math with chemistry, 2.) how does the math of chemistry apply to *their* world *now*, and 3.) how will the math of chemistry help them in the future. My answer usually is that chemistry is the 'connecting science', a gateway that can open their eyes to what exists around them now, and to what possibilities can await them. As I explain this, I see the blank look on some faces, the look of excitement on a few, and for the majority, the look of "here we go again – a teacher that thinks we've got to love this subject because they do". Looking back on how most of my science teachers taught the subject, I empathize with my students' perspective.

Teachers often say that a major problem with students today is that they don't know the basics. But when does a student really get a chance in High School to fix misconceptions of math concepts or to learn math concepts that they did not know that they did not know? What if the math of basic chemistry (which is fundamental math) was presented in a way such that students could rebuild their understandings of the fundamental principles of arithmetic? What if students could walk out of chemistry feeling that they could apply chemistry Principles to become protectors of their house? What if students could understand their applied math so well that they could teach it to their peers or family? What if a student's experience with one amazing year in a subject that surrounds everything that they do were to spark their interest in joining the STEM community? These "what ifs…" are what I strive to address in this unit.

I teach in a Title I High School that has been under the school improvement process for several years. Our demographic population is 99% African American, and 1% Caucasian. We have a free and reduced lunch count well over 80% and my typical student is in the 10 th to 12 th grade. Over 70% of the students who are in my class have failed at least one state standardized test since starting high school, and have received no higher than a "C" in their previous math classes. Most of my students dread math, and when they hear that chemistry is applied math, my students tend to cringe. While my students crave success (usually in the form of wealth), I have noticed an overwhelming sense of pride when it comes to their connections with their family, especially the elderly and younger siblings that many of my students care for. It is my desire to capitalize on this sense of pride for 'protecting their house' that suggested the theme for this unit.

Background and Rationale

The Common Core standards attempt to find a balance between getting the ideas and getting the answers in mathematics. Through the course of this unit I intend to strike this balance with actions rather than creating a checklist of 'mechanical practices' that I am following. The unit will be designed to fill in the gaps of knowledge on fractions and proportions that my students have a serious problem with solving. To achieve this, there is an underlying problem that needs to be addressed. Having taught in my district for five years, I have noticed that many of the value systems that we (the adult professionals) live by simply have no value to our students. I have noticed that many people tell our students that they need to learn and acquire knowledge to succeed. It is only this year that I realized that my students live in a culture that does not value education and higher learning. Upon researching, I realized that what my students are experiencing has been reported world-wide as a problem of students from lower socioeconomic conditions. Dr. John Ogbu, in his report titled "Minority Education and Caste: The American System in Cross-Cultural Perspective" [1] , eloquently explains that students from impoverished backgrounds need to be taught in a way that allows them to relate to the value systems which they hold dear, rather than in a way that has been designed by a society which they perceive has never accepted them. Dr. Ogbu expresses the need for us to understand the lived experience of our learners [2] , and I wholeheartedly agree. This unit aims appeal to the concerns of my students, while developing basic ideas they need to learn to increase their quality of life.

My chemistry students are often lacking some of the basic understandings of arithmetic rules, which severely limits their abilities to comprehend the material in chemistry. From molar ratios of reactions to stoichiometry, it is critical for all of my students to understand fractions, ratios, and proportional relationships in order to succeed in chemistry. While conducting research for this unit, I realized that there was a deficit of information for chemistry teachers who, in the pursuit of filling in knowledge gaps for their students, wanted to teach mathematics fundamentals used in chemistry. The math of basic chemistry (which is fundamental math) needs be taught as an engaging and exciting unit with a purpose to which students can relate. From this unit, I hope to increase my students' quality of life, as well as their belief that learning chemistry can directly relate to their life and their family; I hope to help my students gain the mathematical foundations to protect their house.

Here is the strategy of the unit. My students are often the caretakers of their elders and younger siblings, and as such, are often responsible for determining how much and when to give over the counter (OTC) medications to their family members. This situation presents an opportunity to create an innovative unit that will be personalized for each student in my class. The overarching goal of this unit will be to have each of my students create an OTC dosage chart customized for each family member. Students will record and measure each family members' age and weight. Students will then prove their understanding of the mathematical concepts taught in this unit by:

1. Calculating the appropriate OTC drug dosages for each family member,
2. Justify their methods used in their calculations to their peers, and
3. Review and verify their peers' mathematical calculations.

The resulting information will then, after also having been checked by the teacher, be placed on a poster in an easy to read format so that it can be used as a reference guide. Students will be able to take the poster home to ensure that their family uses the appropriate OTC medications, along with the correct dosages.

The Food and Drug Administration (FDA) regulates the standards of OTC drugs. Drug companies determine the maximum recommended starting dosage (MRSD) by testing the efficacy of active ingredients [3] . Active Ingredients are drug compounds whose chemical properties have a direct correlation to the "diagnosis, cure, mitigation, treatment, or prevention of…disease…or to affect the structure or function of the body…" [4] . The FDA's Center for Drug Evaluation and Research (CDER) approves a human equivalent dose (HED) in the form of the Amt. of Active Ingredient to be delivered in a range of time, also written as (Amount (Amt) of Active Ingredient/time). Or "amt. of active ingredient every time hours" [5]

The HED for adults is calculated based on a human whose age is greater than 12, and who has a normalized mass of 60.0 kg; all adults are assumed to require the same amount of active ingredient over time. For children, the actual mass range of the child is considered, as there are significant physiological differences; thus, (Amount (Amt) of Active Ingredient/time) needs to consider the child's actual weight [6] . The FDA requires that all Active Ingredients of OTC drugs be clearly identified in the label of the drug. The strength of a drug is written as (Amount (Amt) of Active Ingredient)/(Dosage Delivery Type); common dosage delivery types include capsules, tablets, pills, or in the case of liquids, milliliter (mL) of liquid. The adult recommended dosage of drug indicates how much (*n*) of the dosage delivery type should be delivered, based on a multiple of the ratio of Dosage Delivery Type over a certain time period, where Dosage = n x (Dosage Delivery Type)/(time period) [7] . For children, dosage labels for OTC drugs are given in the format of age and weight ranges. Experts agree that if possible, the weight range that the child's actual weight falls in should be used first.

In order for a student to calculate the appropriate dosage, they must understand OTC drug dosage terms, concepts, and units as well as the math of stoichiometric conversions and proportional relationships. To do this, they must understand some key rules of arithmetic that this unit will focus on developing. To prepare for multiplying and dividing fractions, this unit will strive to have students understand repeated subdivision, reconstitution, and renaming. To understand repeated subdivision, reconstitution, and renaming, students must understand the arithmetic of fractions with a fixed denominator. This will be developed using the Common Core approach of first developing the idea of a unit fraction, and thinking of a general fraction as a multiple of a unit fraction. The key to all this work with fractions is the recognition that, in the real world, numbers come with units attached, and careful attention must be paid to the unit to which a number refers. This principle is also basic to stoichiometr [8] .

My students lack a deep understanding of fundamental math concepts. They may understand the mechanics of basic math, but they are lacking the deeper understanding of the arithmetic ideas to apply math in practical contexts. Linear models and area models will be used whenever possible to represent each of the concepts in the unit. All images should be created to scale as much as possible when creating classroom sets. While the

FDA has more complex systems for calculating accurate dosages to use with each OTC drug, this unit will focus on teaching students how to read, interpret, and mathematically manipulate information from OTC drug labels. The end product will not only be applicable for the students, but will be a great starting point for many of the essential stoichiometric conversions that will be necessary in General Chemistry.

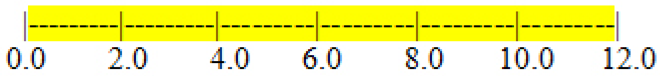
Strategies and Content Objectives

Big Ideas of Lesson 1: Numbers, units, unit and general fractions, division

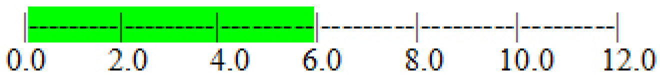
Almost all numbers have units. This lesson will start with exposing students to the various numbers and units that will be used during the year in chemistry (e.g., 12 grams (g) of Carbon, 2 moles (mol) of Hydrogen, 6.02×10^{23} molecules of Oxygen, 22.4 Liters (L) of Nitrogen gas, and 15.0 milliliters (mL) of 2.0 Molar (M) Sodium Hydroxide). The lesson will then describe common numbers and units that students would see in everyday things (e.g., 1 gallon of milk, 2 dozen eggs, 12 square feet, 6 acres of land, 375 mL of water, 12.0 g of Chips, 2 eyes).

Linear and area models will be introduced. A careful introduction will be given to the students regarding not only how to place numbers on a number line, but that the numbers represent an origin and endpoint. With the area models, an emphasis will be placed on the fact that area models consist of congruent rectangles that, when subdivided in two directions, produce equal subrectangles of the whole.

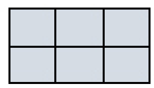
A linear model can be shown to represent one of these number and unit quantities, while an area model can be shown to represent another; this will be the opportunity to allay any misconceptions about how a linear or area model works. Shown below is a linear model representing one 12.0 gram bag of Chips:



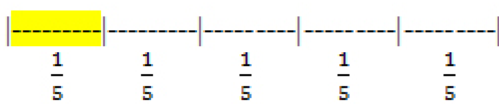
Below is a linear model representing one half of a 12.0 gram bag of chips



Shown below is an area model representing 6 acres of land (Note: This could also equal square feet. This is also a good time to introduce that this represents a 2x3 array):



A unit fraction of a given unit can be obtained by subdividing the original unit into *d* equal parts. Symbolically, this is represented as 1/d , where d is the number of equal parts that make the whole. Shown below is a linear model for representing 1/5 . A line segment is partitioned into 5 equal subintervals, each of which is 1/5 of the original.

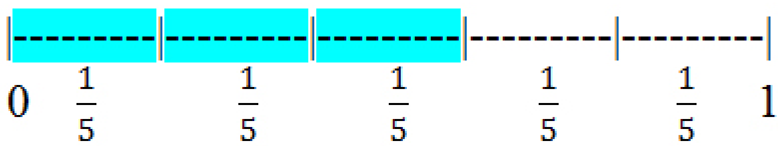


Use this to have students visually grasp that *d* sections (whether it be represented with string, rods, or algebraically) added up would equal one whole unit. With area models, the visual representations of unit fractions are similar. Below is an area model for representing 1/8. It is a rectangle, subdivided into 8 congruent subrectangles, each of which is 1/8 of the original. Note that, as with the linear model, the goal of this representation is to have students visualize that *d* copies of the unit fraction combine to make the whole. (Note: area models are easily represented with graph paper sections).

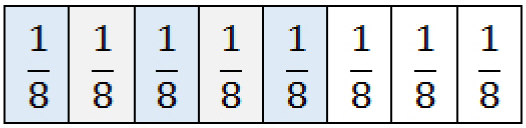
$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$

In all situations, one must be clear about what the whole or unit is; then 1/d is a part such that *d* copies of it make the whole. Before leaving the topic of unit fractions, students must be able to describe and defend an explanation of quantities that are unit fractions.

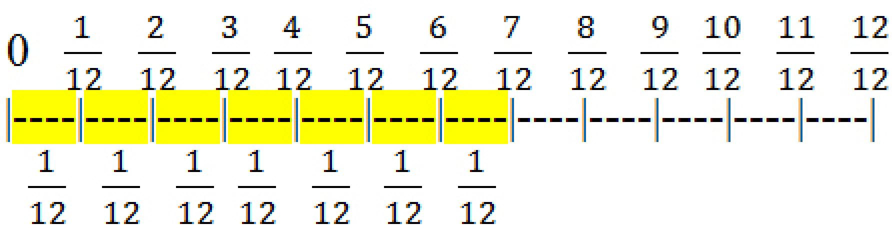
Unit fractions are special examples of fractions. The general fraction is gotten by taking a whole number, *n*, of copies of a unit fraction (1/d) and can be represented by the expression n x 1/d = n/d, where d continues to be defined as the number of equal parts required to make a whole [9] . Shown below is a linear model representing the fraction 3/5, where 3 represents the *n* number of copies (*n*=3) of the unit fraction 1/5 , and thus can represent the rule of general fractions in the form 3 x 1/5 = 3/5 (Note: the slight spacing in highlighted sections represents its own copy of the fraction 1/5)



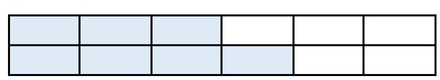
Shown below is the area model representing the fraction 5/8, where 5 represents the *n* number of copies (*n*=5) of the unit fraction 1/8 representing area, and thus can represent the rule of general fractions in the form 5 x 1/8 = 5/8 (Note: the variation in highlights are only to distinguish separate 1/8 unit fractions within the area model).



While students may want to pass over this part of the lesson quickly, it is imperative that they understand that this is a critical part of the unit. Students should be able to not only disaggregate a fraction into its unit fraction and its multiples, but they will need to be able to represent their fractions algebraically using the rule. Finally, students will be expected to find general fractions in real life scenarios, articulate them in sentence format, and present to their peers and the class. As an example to get the class started, the teacher can use the following example: There are 7 eggs left in my carton of 12 eggs. If my carton is taken as the unit, the fraction that represents this quantity is 7/12, where 7 = *n* number of copies of the unit fraction 1/12 (which here is one egg).This relationship can be represented symbolically in the form n x 1/d = n/d as 7 x 1/12 = 7/12 7, and can be represented in a linear model as shown below:



$7 \times \frac{1}{12} = \frac{7}{12}$ can also be represented by the area model shown below:

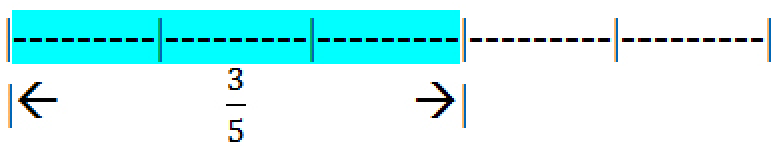


Students will have to create a unit fraction that can be related to some tangible object, create a sentence structure, describe the relationship algebraically, draw representative linear and area models, and then present their examples and models to their classmates. At this time, introduce the fact that unit fractions are present in abundance in measuring systems, where they appear as smaller units such as 1 cc = 1/1000 liters and 1 inch = 1/12 feet.

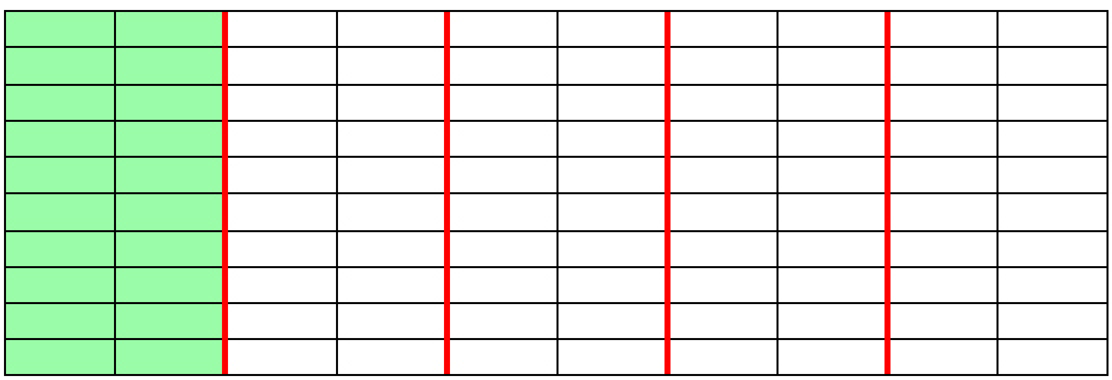
This lesson will conclude with the big idea that a fraction n/d represents a division a/b, where the numerator, *a*, represents the number of copies of the unit fraction 1/b, and the denominator, *b*, represents the equal number of parts to make a whole unit. Students should be given time to digest the idea that the fraction a/b represents the division of a number a divided by *b* equal parts [10]

$$a \div b = \frac{a}{b} = a \times \frac{1}{b}$$

As an illustration, the linear model below represents $3 \div 5 = \frac{3}{5} = 3 \times \frac{1}{5}$



The area model below represents 20 ÷ 100 = 20/100 = 20 x 1/100 and can be understood by students to represent 20 cents, or 1/5 of a dollar. Have students create this representation with a piece of graph paper that measures 10×10. After students highlight the 20 congruent subsections, have them fold the paper at the bolded red lines. Allow students to recognize that 5 equal sections are created, representing 20/100 = 1/5.



This representation is significant in that it represents not only our units of monetary measurement, but our decimal system as well. In fact, the division of a fraction, when entered into a calculator, represents a conversion to the base 10 system where the *d* in a unit fraction of 1/d is represented in iterations of 10, 100, 1000, 10000, but when converted represents 1/10, 1/100, 1/1000, 1/10000, respectively.

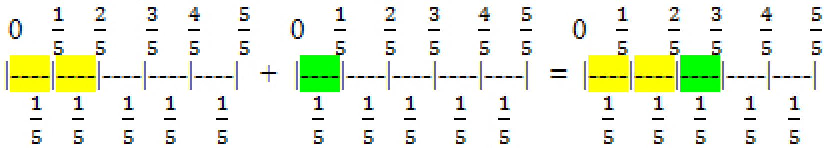
Big Ideas of Lesson 2: Arithmetic of Fractions (+ and x)

Adding fractions with the same denominator is done by adding their numerators. This can be represented symbolically by the rule [11] :

m/d + n/d = (m+n)/d

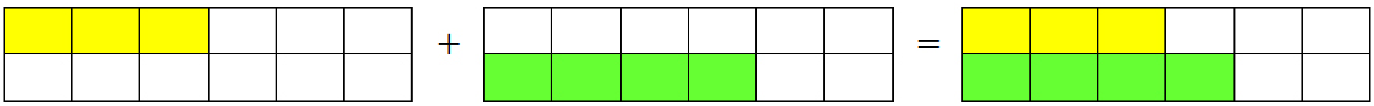
Students should be given linear and area models to help them visualize that this rule is correct. Below are two models. The linear model represents 2/5 + 1/5 = 3/5. Using the rule of addition of fractions with the same denominator, it can be written as: 2/5 + 1/5 = 3/5.

Below is the linear model representation of this expression:

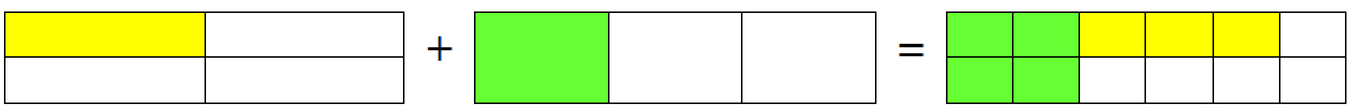


When thinking about addition in the linear model, the general principle is that addition of lengths amounts to placing the lengths end to end; in the above example, the yellow lengths are placed end to end with the green lengths to amount to the total length of 3/5.

Below is an area model representing 3/12 + 4/12 = 7/12. This expression can be algebraically represented as 3/12 + 4/12 = (3 + 4)/12 = 7/12, and visually represented by:



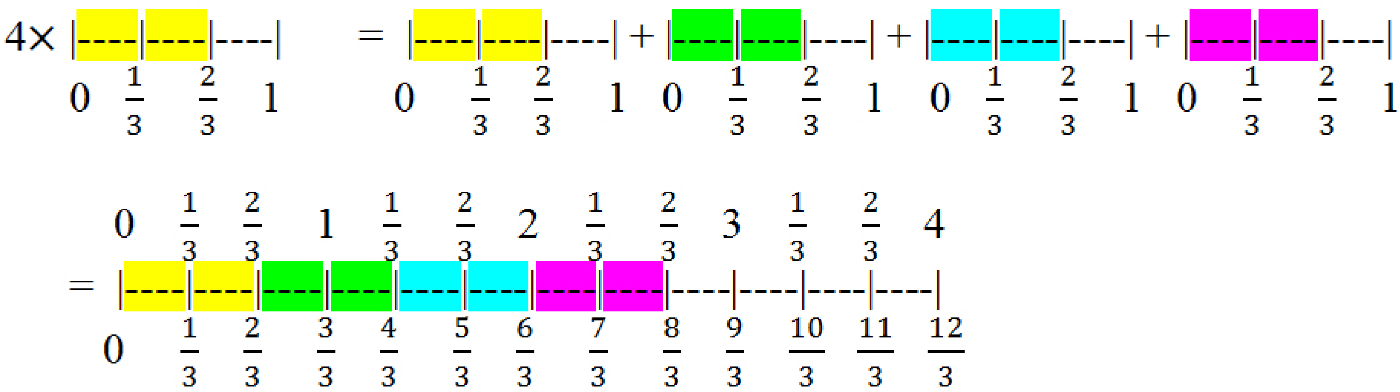
Although the above diagram may be easily understood by the adults, allow the students to delve into the interpretation as to what the empty boxes represent. We don't add the empty boxes, because they are not actually there. Only the highlighted boxes are real. The empty boxes are drawn for purposes of comparing what we actually have (which are the highlighted boxes) with the unit (which here consists of one large box, or 12 small boxes). Further, if students recognize 3/12 = 1/4, or that 4/12 = 1/3, do not hold them back from exploring this idea. Show them the area model visualized below, explaining that we will be reviewing this in an upcoming lesson:



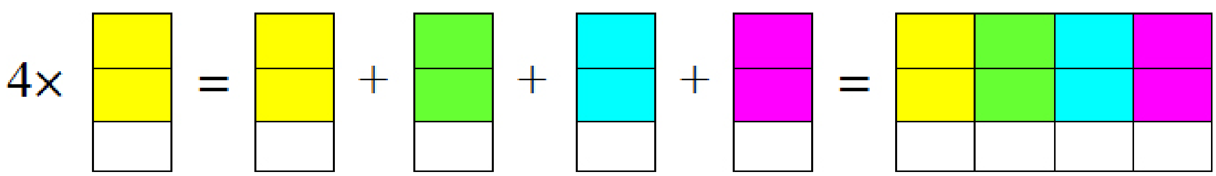
Two concepts will be reviewed regarding multiplication of fractions. First, the multiplication of fractions by a whole number will be explored by continuing to expand the rules. The algebraic representation will expand the rules from general fractions to visualize that the algebraic representation below [12] can be shown with numbers:

$$m \times \left(\frac{n}{d}\right) = \left(\frac{mn}{d}\right)$$

As an example, work through $4 \times \left(\frac{2}{3}\right) = \left(\frac{4 \times 2}{3}\right) = \frac{8}{3}$ with a linear model.



Ensure that students are grasping the principle of placing numbers on the number line. Further, remind them that by putting the length segments end to end, they can show the resulting total length segment. Here is an area model that shows the same product:



Make sure to discuss the models in sentence formats, and have the students do the same. Four of two-thirds is equivalent to four of two of the unit fraction one-thirds, resulting in eight of one-thirds. It is crucial to verbalize and think through the processes learned above out loud with our students, and to give them an opportunity to practice this as well.

Big Ideas of Lesson 3: Repeated subdivision, reconstitution, and renaming

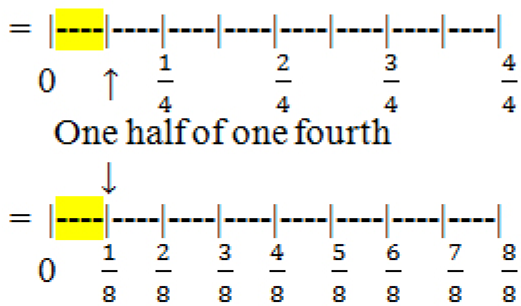
This lesson will have students utilizing linear and area models. Students will justify their answers and persevere through their explanations of why the models work and how they represent their algebraic expressions. This is a critical part of the unit since the skillsets from these three rules are the basis for understanding proportional relationships.

Rule 1: Rule For Repeated Subdivision

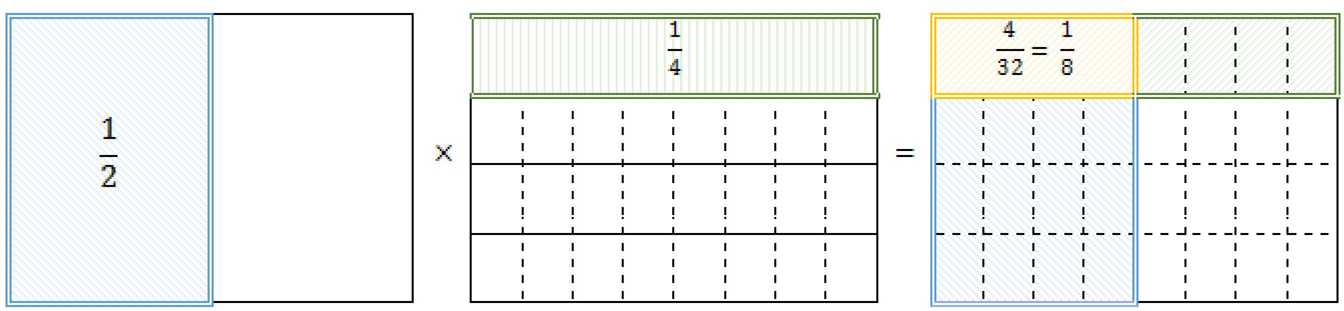
The rule for repeated subdivision follows the same methodology as the previous rules of fractions. It is symbolically described as [13] :

(1/e) x (1/d) = 1/ed

but at this point in the unit, should be described verbally and in sentences. The key is to relate this concept to real life quantities. For example, if we take half of a dime, we know that it represents 5 cents. We will work through examples like this to make the connections to the students. Since a dime represents 1/10 of a dollar (because 10 dimes of equal value represent the whole unit one dollar), (1/2 x (1/10) = (1/(2*10)) (1/20), algebraically represents one half of a dime, resulting in (1/20) of a dollar. Students can logically process that 20 nickels of equal value equal one dollar; based on our rules of unit fractions, we can represent (1/20) of one dollar as a nickel. Via models, numerical problems will also be worked out. For example, in a linear model, (1/2) x (1/4) = (1/(2*4)) = (1/8) and can be represented as follows:



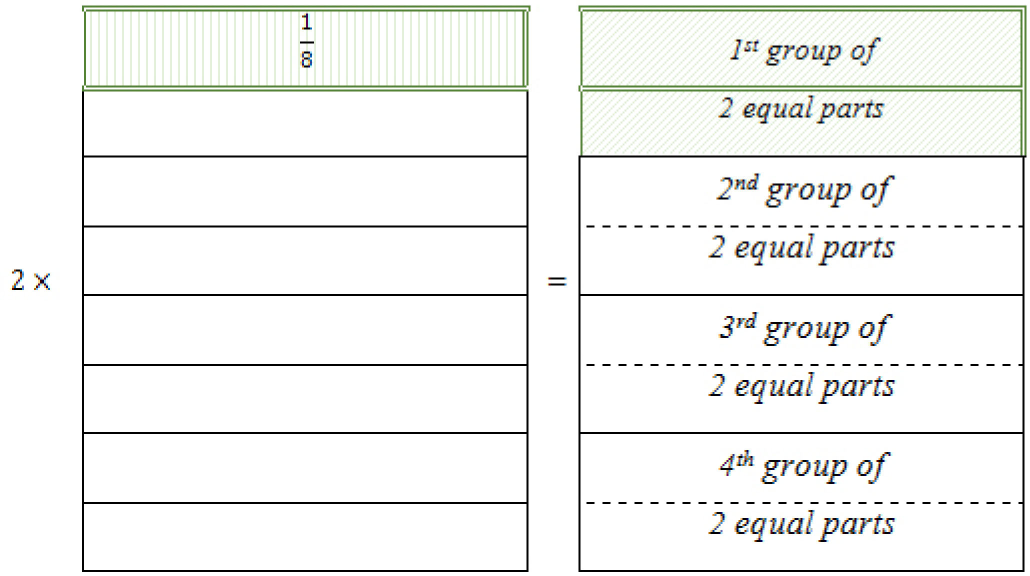
An area model of repeated subdivision of $\left(\frac{1}{2}\right) \times \left(\frac{1}{4}\right) = \left(\frac{1}{2*4}\right) = \left(\frac{1}{8}\right)$ is shown below:



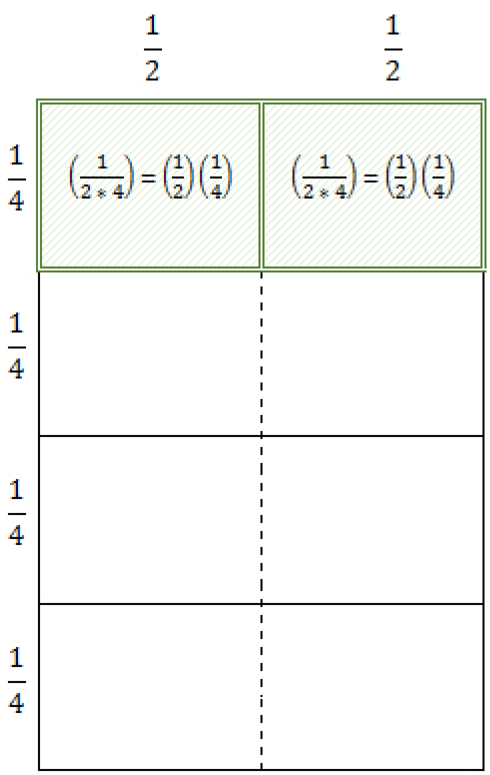
Rule 2: Reconstitution

Reconstitution will be the next topic. The idea of reconstitution is that when a whole number that is a factor of the denominator is multiplied by a unit fraction such that:

E x (1/ed) = (e/ed) = (1/d), *d* groups are formed with *e* equal parts. Reconstitution is significantly easier to visualize with modeling. Seen below is an example of 2 x (1/8) = 2 x (1/(2*4)) = (2/(2*4)) = (1/4) , where there are 4 groups formed of 2 equal parts.



Another way of looking at 2 x (1/8) = 2 x (1/(2*3)), allows for an area model of 2 x (1/2)(1/4)



Although this is significantly easier to recognize visually, it is crucial that students get an understanding of how to manipulate these variables algebraically. The class should spend significant time translating from diagrams, especially area models, to symbolic expressions and back. This part of the lesson will have the students converting common things that they are familiar with. For example: 1 Nickel is equivalent to (1/20) of a Dollar. 2 Nickels are equivalent to 1 dime. Therefore, If we only knew these relationships, we could find out how many dimes are equivalent to 2 Nickels using the Rule of Reconstitution.

$$2\ nickels \times \left(\frac{1\ Dollar}{20\ nickels}\right) = \left(\frac{2 \times nickels \times 1 \times Dollar}{2 \times 10 \times nickels}\right) = \left(\frac{2 \times nickels \times 1 \times Dollar}{2 \times nickels \times 10}\right) = \left(\frac{1 \times Dollar}{10}\right) = Dollar \times \left(\frac{1}{10}\right) = \left(\frac{1}{10}\right) Dollar.$$

This is a critical example in that it will be the first example in which you demonstrate a unit as its own "entity" that must follow all of the rules of arithmetic that we have learned to this point. Rearrangement of the order of numbers and units in the numerator and denominator were rearranged in the example above to show that the rule of reconstitution applies. The term equivalent should also be reviewed to represent two numbers with units whose equivalent values are equal, and thus when divided by each other equal 1 without a unit. This can be algebraically represented with real life examples of money, time, and measurement; for example, 4xQuarters = 1xDollar, 1xHour = 60xminutes, and 1xfoot = 12xinches. However, when these equivalent values are divided in n/d format, we get an equivalent equal to a quantity of one with no units; a (pure) number is a ratio of like quantities. An algebraic representation that most students should be able to visualize is:

$$\left(\frac{4 \times Quarters}{1 \times Dollars}\right) = \left(\frac{1 \times Dollars}{4 \times Quarters}\right) = \left(\frac{1 \times Hours}{60 \times Minutes}\right) = \left(\frac{60 \times Minutes}{1 \times Hours}\right) = \left(\frac{12 \times Inches}{1 \times Foot}\right) = \left(\frac{1 \times Foot}{12 \times Inches}\right) = 1$$

(Note: Give proper time to allow students to digest the idea that multiple equivalents in the n/d format equals one with no units)

Rule 3: Renaming & Introduction to the significance of following the rules with units

The rule for renaming is elegantly simple, and like the other rules, is a combination of the previous rules learned. One representation is [14]

$$\frac{n}{d} = n \times e \times \left(\frac{1}{ed}\right) = \frac{ne}{de},$$

in which having the multiple of e/e can not only be used to find common denominators, but also to convert dimensional units. The process by which n/d = ne/de can be found by simply following the previous lessons in the unit. Given a unit fraction of 1/d , with a number of copies, *n*, of that unit fraction, x 1/d = n/d . If we reconstitute this fraction, we can represent an equivalent fraction n x (e x 1/de) = ne x (1/de). This symbolic rationale is explored to give the reader (teacher) an understanding of the logic sequence that must be understood by the adult learner. For the student, be sure to show how it makes sense in linear and area models, perhaps not even exploring the symbolic derivation. Introduce students to unit conversions in the form of fractions used in chemistry such as 1919

$$\left(\frac{1\ Dollar}{20\ nickels}\right), \left(\frac{4\ Quarters}{1\ Dollar}\right), \left(\frac{1\ Foot}{12\ inches}\right), \left(\frac{1\ mole\ of\ gas}{22.4\ Liters\ of\ gas\ at\ STP}\right).$$

I want my students to learn that given any conversion, they can turn it into an equivalent fraction. They can then use that equivalent fraction to change the unit fraction from the units it is currently in, *d*, to the units that they wish to create, *de*. The conclusion of this part of the lesson should have students able to articulate why n x (e x 1/de) = ne/de when multiplying a whole number (*n*) or fraction (1/d) with an equivalent fraction e_1/e_2 , (whose numerator representation of number and unit, e_1 are equal to the denominator's representation of number and unit, e_2) merely "converts" the original number and unit n/d to a desired number and unit ne_1/de_2. This is the basis for Stoichiometry and should be given the appropriate time throughout the school year. The big takeaway from renaming is, that given any two fractions, you can rename them as fractions with the same denominator. Then if you want to add/subtract them or divide them, it is just like the corresponding whole number operations. Also, you can compare them. For multiplication, you don't need to rename, but the area model argument for computing the product uses the same moves – subdividing in one direction, then in the other – as the discussion of repeated subdivision, reconstitution and renaming.

Big Ideas of Lesson 4: Proportional Relationships

Proportional Relationships utilize all of the arithmetic rules that we have learned thus far. They are a certain kind of relationship between two different variable quantities (usually represented by *x* and *y*). In a real life scenario, a proportional relationship is said to exist when there is a constant k such that

$$y=kx.$$

The *k* factor is called the *constant of proportionality*. If this constant is always created when a relationship exists between the inputs (*x*) and the outputs (*y*), then *x* and *y* are said to exist as a proportional relationship. It allows us to create a relationship between two different values of the variables *y* and *x*. If x_1 and x_2 are two values of *x*, and y_1 and y_2 are the corresponding values of *y*, then $y_1=kx_1$ and $y_2=kx_2$. If we divide both sides of the first equation by x_1, and the second by x_2, we obtain the relationship

$$y_1/x_1 = k = y_2/x_2$$

Here the constant *k* appears as the ratio between any corresponding pairs of *y* and *x*. This is the symbolic explanation as to why proportional relationships are also sometimes expressed as the comparison of two equal ratios. If we divide the each side of the first equation by the corresponding side of the second equation, we get the relationship

$$y_1/y_2 = kx_1/kx_2 = x_1/x_2$$

In this relationship, the constant of proportionality seems to have disappeared, and instead we have a statement that *y* and *x* vary at the same proportional rate: if *x* doubles ($x_2 = 2x_1$), then *y* also doubles ($y_2 = 2y_1$), and similarly for any other proportional change. However, the constant of proportionality can be recovered from the equation $y_1/y_2 = x_1/x_2$ by multiplying both sides by y_2 and dividing both sides by x_1. This recovers the

Relationship $y_1/x_1 = y_2/x_2$. If we think of x_1 (and hence y_1) as staying fixed, and x_2 as varying over all possible values of *x*, with y_2 varying accordingly, then this equation says that the ratio y/x does not change, i.e., it is constant. That constant is *k*. After giving this basic definition of proportional relationships, be sure to give several examples, and discuss carefully why they are proportional relationships. For example, if you can walk

4 blocks in 9 minutes, then at that rate, how many minutes will it take to walk 36 blocks?

$$\frac{4\ blocks}{9\ minutes} = \frac{36\ blocks}{81\ minutes}$$

Another example of a rate proportionality can be applied to the concept of driving at constant speed. Have students talk through a scenario of a driver going 50 miles per hour (mph). Discuss what it means that to drive at "constant speed", allowing your students time to realize that it means you cover equal distances in equal times, or more carefully, that in any two equal time intervals, you go the same distance. So if the driver is going 100mph, then in the first half hour and the second half hour, you cover the same distance, and two of that distance makes 100 miles, so you travel 50 miles in half an hour. And in any quarter hour, you travel 25 miles, and so forth. If you follow this through, you conclude that in *x* hours, the driver drives 100*x* miles, at least when *x* is rational. But perhaps you may just want to declare that driving 100 miles an hour means that he drives 100*x* miles in *x* hours. Assuming he does not get pulled over or wreck, how long will it take to drive 50 miles?

The statement that "he drives at a constant speed of 100 miles per hour" means that, in driving for *x* hours, he goes d = 100 *x* miles. So asking how long it takes to go 50 miles is asking for the *x* that satisfies

$100x = 50$.

Dividing both sides of this equation by 100 gives $x = 50/100 = 1/2$. The miles traveled and hours driven are the variables, with "100" representing the constant in the proportional relationship between them. Students will practice various proportional relationships including drug conversion problems, and molar ratio problems. For example, if a 60 kg person should take 50 mg of medicine, how many mg of medicine should a person take if they weigh 73 kg? Make sure to state the fundamental assumption that the correct level of medication is proportional to weight. Then point out that, in this case, we are not given the constant of proportionality, so we have to use the second formulation of proportional relationship $y_1/x_1 = k = y_2/x_2$. In this example, the setup would let

$$\frac{y_1}{x_1} = \frac{60\ kg\ person_1}{50\ mg\ medicine_1}\ and\ \frac{y_2}{x_2} = \frac{73\ kg\ person_2}{x_2\ mg\ medicine_2}\ and\ therfore\ \frac{y_1}{x_1} = \frac{y_2}{x_2}\ .\ \text{Display.}$$

Students will then solve for *x.*

Big Idea of Lesson 5: Principles of Drug Dosages

Basic information of Pharmacology will be reviewed utilizing units prepared by the FDA [15] . FDA regulations regarding OTC Drug labeling will be reviewed. This lesson will also rely on the online review activity created by the FDA which will review common symptoms and relief terms, what drug labels must disclose, and other critical terms such as active ingredient, and strength per dosage type [16] . Explain to students that, although it is not strictly true, a good rule of thumb is that drug dosage for someone of a given age should be proportional to weight. Then provide a list of constants of proportionality for various age bands, or to be sometimes more challenging, give the appropriate dosage for someone of a given weight, and ask your students to find the constant of proportionality [17] .

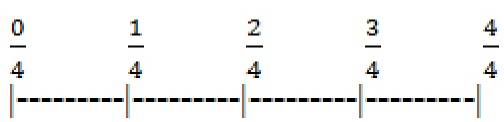
Big Idea of Lesson 6: Creating your dosage chart ~ Culminating Activity

The goal of the unit is developing this chart. To make their personal chart, students will take the weight measurements and record the age of all members of their household. Students will also record on their chart the appropriate information (based on the template provided in Appendix B) from each of the OTC drug medications that may be used in their household. Students will then calculate the appropriate dosages for all of the OTC medicines on the chart. Appendix B has not been provided as a comprehensive chart. Rather, it has been provided as a guide to serve you in determining what information needs to be recorded in the students' charts; included in the appendix are common OTC medications that have single and multiple active ingredients. It is recommended that ALL recommended dosages be reviewed via the manufacturer's websites at the time of the unit. Please also note that separate dosage charts should be created for infants, youth, and adults. After you are confident that the students have accurately transcribed the information from their household OTC medication packages, have the students conduct a peer review to look for possible mistakes.

Once the charts are created, have students begin calculating their household's dosages. The key to this section is that the students are going to have to describe carefully the steps that they took to come to their final answers. They must explain their reasoning in writing. Also, students will have to defend their answers, as well as explain the process of the mathematics, and why the conversions work to the class. Finally, after peer reviews, students will write their calculations with explanations on the back of their poster so that they can refer to their chart calculations for future modifications.

Activities Corresponding to Big Ideas of Lessons

All activities will have students working with various manipulatives to visualize linear and area models presented in the Big Idea Lessons above. When linear models are described, the term *marks* will be used to describe the perpendicular lines that are drawn on the number line to represent the relative distance on a number line. The term *segment* will be used to describe the spacing increment between two points along the number line. All segments will be equal (representing 1/d equal segments) throughout all the linear model activities. Thus, the number line below will be described as "a number line created with 5 progressive 1/4 marks from 0/4 to 4/4, and 4 segments.



Area models will utilize array protocols, which is to say that they will be written as *r*×*c*, where *r* is the number of equally divided rows (representing 1/r equal horizontal sections), and *c* is the number of equally divided columns (representing 1/c equal vertical sections) to build the area model. Subrectangles will be used to describe the 1/(r xc) areas (which will always be equal for this unit) created within the array from the intersecting horizontal and vertical sections. Thus, the array below will be described as a 2×3 area model, with 6 resulting subrectangles.

	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$
$\frac{1}{2}$	$\frac{1}{2 \times 3}$	$\frac{1}{2 \times 3}$	$\frac{1}{2 \times 3}$
$\frac{1}{2}$	$\frac{1}{2 \times 3}$	$\frac{1}{2 \times 3}$	$\frac{1}{2 \times 3}$

Activity 1: Numbers, units, unit and general fractions, division

Prepare your linear models by cutting a clothing tape measure into 4 inch segments. Prepare your area models by cutting egg cartons such that the dimples of the egg carton can be represented as 2×1, 2×2, 2×3, 2×4, 2×5, and 2×6 area models. The goal is to have each student able to play with and manipulate one linear model and at least 4 area models through the activities that will follow.

After covering the big idea of the lesson, hand each student one penny, have them place it in one dimple of one of their area models, and draw the representation on graph paper. Start the example by explaining (with your own example) your unit fraction created and represented by one penny in your area model. Have students quickly state their unit fraction represented by the penny in their area model while holding their model for the class to see. Have students then find the point on their linear model that would represent the unit fraction represented by the area model.

Once students are comfortable with this concept, have the students write their own examples of a Unit Fraction, along with a corresponding General Fraction that represents n number of copies of the unit fraction, culminating with them explaining how the general fraction represents a division. Students must create 3 examples with units: one example of time, one example of money, and one example of grades; all examples are to be written in sentence format, drawn in linear and area models, and, as a bonus for high performing students, drawn in any other visual representation that can help them explain and defend their example. Students will be called upon in random order to present their ideas (Note: be clear with the students that at this stage, your expectation is that they are able to explain what their fractions are fractions of, i.e., that they are aware of their unit). Each student will have 1 minute to explain their idea, and 1 minute to answer any questions.

Activity 2:

Have students use the graph paper and egg carton area models that they drew and were given in Activity 1 to prove that the rule of addition of fractions holds true. Have students prepared to explain and defend their position. The goal of this activity is to have students be able to correlate the variable representation of the rule of addition of fractions to their drawings. Have students form groups with the objective of finding the highest number of combinations of adding fractions that can be created from their graph paper representations.

Using numbers from 1-10, have students create linear and area model representations on graph paper of a unit fraction and area fraction of their choosing. Have students rotate around the room to "combine" (find models with the same number of equal units) their linear models with other linear models, showing not only a picture of their combined representations, but how the visual results can be represented mathematically. This is a good opportunity for students to demonstrate two key ideas. First, they should be able to demonstrate an understanding of how the number line works. Second, students should be able to demonstrate that when dealing with addition of fractions with common denominators, the result can be represented by laying the segments end to end.

When students feel secure with the linear models, repeat the same procedure of rotation and "combination" with other students who have similar subrectangles. With area models, students should be able to demonstrate 2 key ideas. First, students should be able to demonstrate an understanding of the language of mathematics by using proper nomenclature when discussing the addition of fractions and multiplication of fractions with a whole number. Second, students should be able to articulate how their models represent the symbolic formulas presented at the beginning of the lesson.

Activity 3: Repeated Subdivision, Reconstitution, and Renaming

Using the same logic of the previous activity, have students prove that 1/2 of 1/4 of one dollar is equal to 1/8 of a dollar. This can be demonstrated as follows. Fold a one dollar bill lengthwise in half. Fold it again in half, creasing the edges. Fold the bill in half widthwise, creasing the edges. Upon opening the dollar bill, students should be able to visualize that there are four vertical sections and two horizontal sections, creating eight subrectangles. Discuss how the vertical sections represents four sections of 1/4. Cut one of the vertical sections of the bill; this represents the 1/4 section. Proceed to cut the 1/4 section in half. Ask students to prove that the piece of dollar bill in your hand represents 1/8 the area of the original dollar. Have students verbalize why this idea of repeated subdivision works. Have premade sections of graph paper (see example in the big idea of lesson above) to have students represent various examples of repeated subdivision with increments of

$$\frac{1}{2}, \frac{1}{3}, \frac{1}{4}, \frac{1}{5}, \frac{1}{6}, \frac{1}{7}, \frac{1}{8}, \frac{1}{9}, \text{ and } \frac{1}{10}.$$

Students should present their example to small groups, and have each group report out as to what they learned from this activity. Notice that if you want to rename 2/3 and 3/4 to fractions with the same denominator, you will need 1/12. If you want to rename 2/5 and 1/4, you will need 1/20.

Expand the image of the front of a $100 bill such that it measures 5 inches × 10 inches and have multiple copies prepared for students. Have students find ways to create 10 equal sections. Students will then find ways to create these sections on graph paper to represent the "breaking up" of their $100 bill. Have students prove the idea of reconstitution by "breaking up" their $100 bill in increments of $10, $20, and $50 equal sections with their copies. Repeat the exercise, having students create 100 equal sections. Have students prove the symbolic formula of reconstitution holds true by "breaking up" their $100 bill in increments of $1 and $5 increments (or subrectangles). Assist students with processing the idea that, for example, $5 represents 1/20 of the $100 bill, Two $5 Bills represent $10, and mathematically represent 1/10 of a $100 bill.

Review the idea of equivalent values from the big ideas lesson section above. After you have done so, have each student draw their own examples of equivalent values for money, time, and measurement; the pictures should represent the *n* and *d*, and students should have the corresponding number and unit values labeling their pictures. Students should report out their examples. When the class has reported out, have everyone in class stand side by side in a line and show their equivalent values. Ask them what the result of 1,234,567,890 dollars times ALL of their equivalent values would result in, and have the students verbalize their understanding of the combination of the various rules of arithmetic at this point until they come to the correct conclusion that they would have a result of $1,234,567,890. Explain to them that this is the core idea of stoichiometry and lead into the rule of renaming with an emphasis on the significance of following the rules of mathematics that we have learned when dealing with units.

For renaming, use examples of money. Have students mathematically prove that 8 dollars is 160 nickels if all we know is that 1 dollar = 4 quarters and 2 quarters = 10 nickels. Continue with these types of monetary examples until students are comfortable defending their answers with the logic of the rules for multiplying and dividing fractions, reconstitution, and renaming. Have students work through (verbally) similar problems converting time, and finally various forms of measurement.

Activity 4: Proportional Relationships

Cut pieces of string in 3 inch equal lengths so that each student has the same size piece of string. Using an overhead projector or document camera, project the string on a wall; have students calculate how many times bigger the 'wall string' is in comparison to the actual string. Have students verbally work through problems concerning how much money they would make if they made $20 for every 2 hours they work versus if they made $5 for every 30 minutes that they worked. Facilitate the students in coming up with their own proportionality constants in each of these examples (which will result in the same amount, but may have different units). Giving common stoichiometry examples, have students practice not only the algebraic manipulation of proportional relationships, but having to explain, in each of their examples, why the rules of proportional relationships work.

Segue into percentage proportional relationships by cutting out 10×10 area models on graph paper. Have students fold into 10 columns representing 10 questions on a test. Have the students shade how many questions they get correct. Have students proceed to verbally prove why their number represented a percent, which is simply a fraction with a unit fraction of 1/100, and a proportional relationship. While students are presenting, the other students in the class should be writing the example of the presenting student algebraically. The result is that all students should have as many examples as students in the class of solving for *x* when a proportional relationship exists such that $y_1/x_1 = k = y_2/x_2$.

Activity 5: Principles of Drug Dosages

Give students a laymen's explanation of the terms dosage, dosage type, strength, active ingredients, and inactive ingredients; students will walk through the unit created by the FDA on how to identify various aspects of an OTC label [18] .

Students will then review the FDA's online activity on OTC drugs which reviews common symptoms and how to determine, by reading the labels, what drugs are appropriate to take [19] .

Students will make, per class, a list of the terms of intended use (e.g., Nasal Decongestant and Cough Suppressant) and the corresponding symptoms in 'common language' that all members of their family can understand.

Students will be given the homework assignment of creating a list of the people whom they live with and or care about. The list will specify their families' weights, ages, and any allergies that they may have to certain medications.

For every OTC drug that the students have in their household, students will be asked to create a chart similar to the template shown in class (from Appendix B) listing the Name of the OTC Drug, Intended Use(s), the Active Ingredient(s), the Concentration of Active Ingredient(s) per Dosage Type, and the Direction(s) of Dosage per time. This will be the preliminary list from which the culminating lesson will occur.

Activity 6: The Dosage Chart – Culminating Activity

Students will be asked to create a personalized, poster sized, family dosage chart.

The backside of the poster should have 4 equally divided sections. Section 1 should include a list of common OTC Drug intended use terms and an explanation of the symptoms which those terms represent in plain language. Section 2 should have each family member's name, age, approximate weight, and the calculations used to determine the dosage per time for each OTC Drug (note: since this is the largest section, students may need to staple their work onto this section). Section 3 should have any warnings or known allergies of any family members. Section 4 should have key contact information for poison control, and websites of the various manufacturers of OTC drugs that are commonly used in the students' household.

The front of the poster should 2 equal sections. Section 1 should have the dosage chart, with the rows representing each family member. The columns should have the age, weight, and Dosage per time for the Individual OTC drugs that are commonly found in the house. Section 2 should have an explanation of each OTC Drug and its intended uses.

Appendix A: Implementing Standards

CH1-The student will investigate and understand that experiments in which variables are measured, analyzed, and evaluated produce observations and verifiable data. Key concepts include:

1. CH.1d: manipulation of multiple variables
2. CH.1f: mathematical and procedural error analysis
3. CH1g: mathematical manipulations including units, linear equations, graphing, ratio and proportion, significant digits, and dimensional analysis

CH4-The student will investigate and understand that chemical quantities are based on molar relationships. Key concepts include

1. CH.4a: Avogadro's principle and molar volume;
2. CH.4b: stoichiometric relationships;
3. CH.4c: solution concentrations

CH5-The student will investigate and understand that the phases of matter are explained by kinetic theory and forces of attraction between particles. Key concepts include

1. CH.5a: pressure, temperature, and volume
2. CH.5b: partial pressure and gas laws

CH6-The student will investigate and understand how basic chemical properties relate to organic chemistry and biochemistry. Key concepts include

1. CH.6a: unique properties of carbon that allow multi-carbon compounds
2. CH.6b: uses in pharmaceuticals and genetics, petrochemicals, plastics, and food

Appendix B: FDA Approved OTC Dosages

Setup for Infants Common OTC Drug Dosage Chart

Active Ingredient(s)	Common Brands	Usual Concentration per Dosage Type	Recommended Dose for Age & Weight Range			Uses
			<6 months <12 lbs	6-11 months 12-17 lbs	12-23 months 18-23 lbs	
Ibuprofen	Advil Motrin	$\frac{50\ mg}{1.25\ mL}$		$\frac{50\ mg}{4\ hours}$	$\frac{75\ mg}{4\ hours}$	Aches, pains, and temporarily reduces fever
Acetaminophen	Tylenol	$\frac{40\ mg}{1.25\ mL}$	$\frac{40\ mg}{4\ hours}$	$\frac{80\ mg}{4\ hours}$	$\frac{120\ mg}{4\ hours}$	

Setup for Childrens Common OTC Drug Dosage Chart

Active Ingredient(s)	Common Brands	Usual Concentration per Dosage Type	Recommended Dose for Age & Weight Range					Uses
			2-3 years 24-35 lbs	4-5 years 36-47 lbs	6-8 years 48-59 lbs	8-10 years 60-71 lbs	11 years 72-95 lbs	
Ibuprofen	Advil Motrin	$\frac{100\ mg}{1\ tablet}$			$\frac{200\ mg}{4\ hours}$	$\frac{250\ mg}{4\ hours}$	$\frac{300\ mg}{4\ hours}$	Aches, pains, and temporarily reduces fever
Acetaminophen	Tylenol	$\frac{80\ mg}{1\ tablet}$	$\frac{160\ mg}{4\ hours}$	$\frac{240\ mg}{4\ hours}$	$\frac{320\ mg}{4\ hours}$	$\frac{400\ mg}{4\ hours}$	$\frac{480\ mg}{4\ hours}$	

Dextromethorphan	Delsym 12 Hour	$\frac{30\ mg}{5\ mL}$		$\frac{2.5\ mL}{12\ hours}$	$\frac{5\ mL}{12\ hours}$		Cough
Acetaminophen Dextromethorphan HBr Guafenesin Phenylephrine HCl	Mucinex Multi-Symptom Cold & Fever	Acetaminophen $\frac{325\ mg}{10\ mL}$ Dextromethorphan HBr $\frac{10\ mg}{10\ mL}$ Guafenesin $\frac{200\ mg}{10\ mL}$ Phenylephrine HCl $\frac{5\ mg}{10\ mL}$			$\frac{10\ mL}{4\ hours}$		Fever Reducer, Stuffy Nose, Cough, Chest Congestion, Breaks up Mucus
Loratadine	Claritin	$\frac{5\ mg}{5\ mL}$	$\frac{5\ mL}{24\ hours}$		$\frac{10\ mL}{24\ hours}$		Runny Nose, Sneezing, Itchy, Watery Eyes, Itchy Nose or Throat
Fexofenadine HCl Antihistamine	Allegra Allergy	$\frac{30\ mg}{5\ mL}$	$\frac{5\ mL}{12\ hours}$				
Diphenhydramine HCl	Benadryl	$\frac{12.5\ mg}{5\ mL}$	Doctor	Doctor	$\frac{12.5\ mg}{4\ hours}$	$\frac{25.0\ mg}{4\ hours}$	

Setup for Adult OTC Drug Dosage Chart				
Active Ingredient(s)	**Common Name**	**Usual Concentration per Dosage Type**	**Recommended Dosage**	**Uses**
Ibuprofen	Advil Motrin	$\frac{200\ mg}{1\ tablet}$	$\frac{200\ mg}{4\ hours}$	Aches, pains, and temporarily reduces fever
(A) Dextromethorphan (B) Guaifenesin (C) Phenylephrine	Tussin CF Robitussin Peak Cold	Dextromethorphan $\frac{10\ mg}{5\ mL}$ Guaifenesin $\frac{100\ mg}{5\ mL}$ Phenylephrine $\frac{5\ mg}{5\ mL}$	$\frac{10\ mL}{4\ hours}$	Cough, Chest Congestion, Stuffy Nose
Loratadine	Claritin RediTabs	$\frac{10\ mg}{1\ tablet}$	$\frac{10\ mg}{24\ hours}$	Runny Nose, Sneezing, Itchy, Watery Eyes, Itching of the nose or throat
Chlorpheniramine Maleate Antihistamine	Chlor-Trimeton	$\frac{12\ mg}{1\ tablet}$	$\frac{12\ mg}{12\ hours}$	Runny Nose, Sneezing, Itchy, Watery Eyes, Itching of the nose or throat

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